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RESEARCH PAPER

Bird and Plant Diversity in Tropical Landscape Mosaics in East Usambaras, Tanzania

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Abstract The role of land uses outside protected areas in conserving tropical biodiversity remains poorly understood and contested. This paper summarizes the results of plant and bird surveys conducted in three rural landscapes in the East Usambara Mountains of Tanzania, covering a gradient from Village forest reserves to tree-based and other agricultural land uses. The species richness and occurrence of conservationally important species across the land uses were analyzed. Twelve plots of 0.2 ha, stratified among land use types, were established to survey the large trees, with sub-plots of 1×40 m for tree saplings, shrubs and non-woody plants, and 5×40 m plots for small trees. Avian richness was measured in the same sites as the plants through mist netting and timed species counts. The village forests had higher plant species richness and more conservationally important plant species compared to other land uses. Agroforest and fallows supported a relatively high number of plant species, but the species composition was largely different to the adjacent village forests. Bird species of conservation importance were recorded across all land uses. Village forest reserves and some of the tree-based agricultural land uses were found to contribute to biodiversity conservation goals in tropical landscape mosaics. There is a need to better integrate them, and address their

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multiple functions, in village land-use planning and conservation efforts at the landscape level.

Keywords Species richness · Biodiversity conservation · Village forest reserves · Agricultural land · East Africa

Introduction

The conservation of tropical forest biodiversity outside of protected areas has become an important goal in the global conservation and development thinking and practice (Zuidema and Sayer 2003; Wiersum 2003; Sayer et al. 2005; Munishi et al. 2008). This interest is fuelled by the exhaustion of opportunities to allocate additional forest to conservation and the fact that large-scale conversion of forest to other land uses has already occurred in many landscapes (Harvey and Villalobos 2007).

The role of lands and trees outside of protected areas in species conservation remains an area of debate. Some argue that closed natural forest provides the best habitat to protect many rare forest dependent species and that agricultural practices do not help to achieve species conservation objectives (e.g. Naidoo 2004). Others suggest that agricultural land uses that support trees, such as agroforestry, may be conducive to species conservation within rural landscapes (e.g. Noble and Dirzo 1997; Bhagwat et al. 2008; Hall et al. 2011). Agroforestry practices may increase the levels of wild biodiversity on farmland compared to more open land uses and support the conservation of biodiversity in remnants of natural habitat that are interspersed with agricultural areas in tropical land use mosaics by enhancing landscape connectivity (Harvey et al. 2006; McNeely and Schroth 2006).

In many tropical regions, specific information on biodiversity values of land uses outside core protected areas remains scant. Evidence is increasing of some elements of the landscape mosaic, such as small forest patches, riverine forest and traditional agroforests, supporting a diversity of native or forest dependent species (e.g. Harvey et al. 2006, Hall et al. 2011). Incorporating these areas in land use planning may help to minimise the trade-offs between conservation and development goals. Conservation through land use planning needs to be based on careful analysis of local ecosystems and implications of management options for conservation and other goals, including improvement of local livelihoods.

Protected areas are generally managed by central governments with minor involvement of communities. There has been a growing interest in community-based approaches to forest management and conservation of biodiversity during the last two decades, as suggested by Pagdee et al. (2006) and Lele et al. (2010). Community-based conservation approaches include financial subsidies to communities from the government or external agencies, sharing of revenue from protected areas with the communities, as well as building of community-level resource management institutions (Lele et al. 2010). One of these community-based approaches to forest conservation in Tanzania is the establishment of village forest reserves (VFR), managed by communities or groups of villagers.

In Tanzania, the area of forest under the control of communities has increased during the past 15–20 years (Blomley and Ramadhani 2007). Previously, most forests were formally managed by the government. The forest management rules and collection of the revenue by the government has not been enforced efficiently, and management planning has also been incomplete (Blomley et al. 2009; Milledge 2009). In 2008, 12.8% of the total forest area was under some form of Participatory Forest Management or PFM (MNRT and FBD 2008). In PFM, the communities can have a full management responsibility of reserves established on village land under Community-Based Forest Management,[1] as in the case of VFRs. PFM has been found to have positive outcomes for forest conservation, mainly through more effective control of human activities (Blomley et al. 2008). Even small forest areas managed by villagers have been shown to contain substantial forest diversity in some regions of Tanzania (Hall et al. 2011).

This paper contributes to the knowledge of the biological importance of the rural landscape surrounding protected forests by studying the species composition of various land uses, including VFRs, tree-based and more open agricultural lands, in the East Usambara Mountains. This site is of interest due to its unique biodiversity and rapid rate of forest conversion. The study area is part of the Eastern Arc Mountains that are famous for their high level of plant and animal diversity and numerous endemic species (Rodgers and Homewood 1982; Myers et al. 2000; Burgess et al. 2007). Despite the long history of botanical and ecological research in the East Usambaras, the habitat mosaics partly created by and largely used by the local inhabitants have been poorly studied. Most biodiversity surveys are concentrated on Amani Nature Reserve, one of the government protected areas, Catchment Forest Reserves[2] and protected forests on private tea estate land. A conservation organization, Frontier Tanzania, has conducted biodiversity surveys in the government forest reserves under a large forest conservation program (EUCAMP 2002).

Hall et al. (2011) conducted a floristic survey of agroforests in the East Usambaras and found that agroforests, when managed traditionally (without chemical inputs and maintaining native tree species), harboured an average of 65% of the tree species found in protected forests. Moreover, forest edges and agricultural landscapes in the same region provide important foraging sites for many birds, including some threatened and endemic species (Borghesio et al. 2008). Munishi et al. (2008) observed high richness of tree species on farms in the West Usambara Mountains.[3]

The objectives of this research were (1) to identify the floristic species richness, particularly the species of conservation importance (threatened and endemic species) that occur in village forests, agroforests and more open land uses typical in

[1] Management goals of Community-Based Forest Management include sustainable use and conservation of forest resources (e.g. Blomley et al. 2009).

[2] The term *government forest reserve* is used here to refer to the forests protected by the central government, including Nature Reserves and Catchment Forest Reserves. Government forest reserves have been established in mainland Tanzania since the colonial era.

[3] Munishi et al. (2008) did not specify the characteristics of the farming systems, but stated that trees were not the major crop.

the rural landscape (2) to determine the plant species composition of these land uses to assess their conservation importance (3) to assess bird fauna in the rural landscape, including the degree of forest dependency of birds and the existence of species of conservation importance.

That particular native and rare species are found on specific land uses does not mean that these areas automatically contribute to conservation goals. The significance of land uses for conservation depends also on population dynamics and pollination and breeding patterns. However, the existence of native and rare species implies that such areas have a potential to contribute to conservation goals, if the land use is planned carefully, and the whole landscape is managed sustainably. This information may thus assist in understanding how the agricultural mosaic should be targeted when planning conservation of biodiversity in tropical landscape mosaics.

In the following section, the characteristics of the East Usambara Mountains and the study sites are first outlined. The research methods are then described. The results section highlights the richness of plant and bird species across the land uses and the occurrence of endemic and threatened species. Finally, the role that the VFRs and agricultural land uses might have in maintaining conservationally important species and contributing to conservation goals on the landscape scale is discussed.

The Research Site

The East Usambara Mountains cover an area of 1,082 km^2 and are located in Tanga region in Tanzania. The altitude of the area ranges from 130 m in the lowlands to 1,506 m in the highlands (Burgess et al. 2007). Rainfall is greatest at higher altitudes and in the south-east of the mountains, increasing from 1,200 mm annually in the foothills to over 2,200 mm at higher altitudes.

The East Usambara Mountains have 35 Eastern Arc endemic and 42 near endemic terrestrial vertebrates (Burgess et al. 2007). Eastern Arc endemic species are only found in the ecosystems of the Eastern Arc Mountains whereas Eastern Arc near endemics are confined mainly in the Eastern Arc ecoregion, but also occur in one or more of the WWF-defined ecoregions near these mountains, i.e. the Northern Inhambane–Zanzibar Coastal Forest Mosaic and the East African Montane Forests. Forty tree species that are endemic or near-endemic to the Eastern Arcs have been identified in the East Usambaras. The area also contains six out of the 19 Eastern Arc endemic bird species and 13 out of 26 Eastern Arc near endemic bird species. (Burgess et al. 2007.) The East Usambaras supplies water to Sigi River, a vital source of water for the local communities, as well as to Tanga city.

Local people mainly depend on small-scale farming, including subsistence and cash crop farming. A typical village landscape is a diverse mosaic of land uses, including settlements, fields of monoculture and mixed crops, fallows, and areas of degraded forests, usually on ridges and bordering streams and agroforests, where villagers can extract tree products for local use. Sugarcane, cardamom, cinnamon and cloves are common cash crops in the uplands. For subsistence, bananas, beans,

yams and cassava are commonly cultivated in the higher elevations. In the lower slopes of the mountains, farmers cultivate oranges and teak for cash, and maize and beans for subsistence.

The proportion of recent forest loss in the East Usambara Mountains is high compared to other Eastern Arc blocks. A recent study indicates that the proportion of humid Eastern Arc forest lost between the 1970s and the 2000s to be 12%, decreasing from 29,900 ha to 26,300 ha in the East Usambara Mountains (FBD 2006; Hall et al. 2009). Mostly, the deforestation has taken place outside the government forest reserves. The rate of deforestation has increased during the 21st century (Hall 2009).

Population growth and expansion of small-scale agriculture are considered as the major threats to the Eastern Arc forests (Newmark 2002). In the East Usambara Mountains, other direct threats include harvesting of fuelwood and building materials, unauthorized harvesting of timber for sale and gold mining that occur both in the submontane zone and in the lowlands, and fires, especially in the lowlands (Lovett 1985; Burgess and Kilahama 2005; Leonard et al. 2010). Underlying these are broader institutional, political and economic factors, including market shifts and poor governance (Blomley et al. 2009).

About 74%, or 31,000 ha, of the natural forest area of the East Usambaras was reserved in the late 1990 s (Newmark 2002). Since then, the protected area has increased, due to establishment of new government forest reserves. There are presently 32 forest reserves in the East Usambaras, including two Nature Reserves, 10 Catchment Forest Reserves, 18 village forest reserves, and private tea estate forests with a total area of nearly 328 km^2 (Fig. 1). A small amount of forest is on other village land and private land.

Since the end of the 1980s, a number of projects and organizations—including the World Conservation Union, WWF, TFCG (Tanzania Forest Conservation Group[4]), and the East Usambara Conservation Area Management Program (EUCAMP)—have supported forest conservation in the East Usambaras. One of the projects' objectives has been to increase the connectivity between the forest reserves. Establishment of new VFRs is also targeted towards this goal. Many villages have created bylaws to support forest conservation (Rantala and Lyimo 2011).

The study areas include the villages of Misalai and Shambangeda in the uplands (with elevation above 500 m), and Kwatango in the lowlands. The upland villages are located close to large tea fields and eucalypt plantations, and Misalai is also close to Nilo Nature Reserve. Kwatango is bisected by the Sigi River and neighbours large forest reserves. Small-scale plantations of teak have also been established in Kwatango. The uplands and lowlands differ in terms of rainfall and temperature and thus also in the crops commonly cultivated. Misalai and Shambangeda are located in the sub-montane forest zone, which supports dense humid closed forests and has no dry season, whereas Kwatango is located in the

[4] TFCG is an NGO supporting and implementing conservation activities in Tanzania. Its history is related to the growing activism among the conservationists working in the Eastern Arc Mountains at the end of the 1970s.

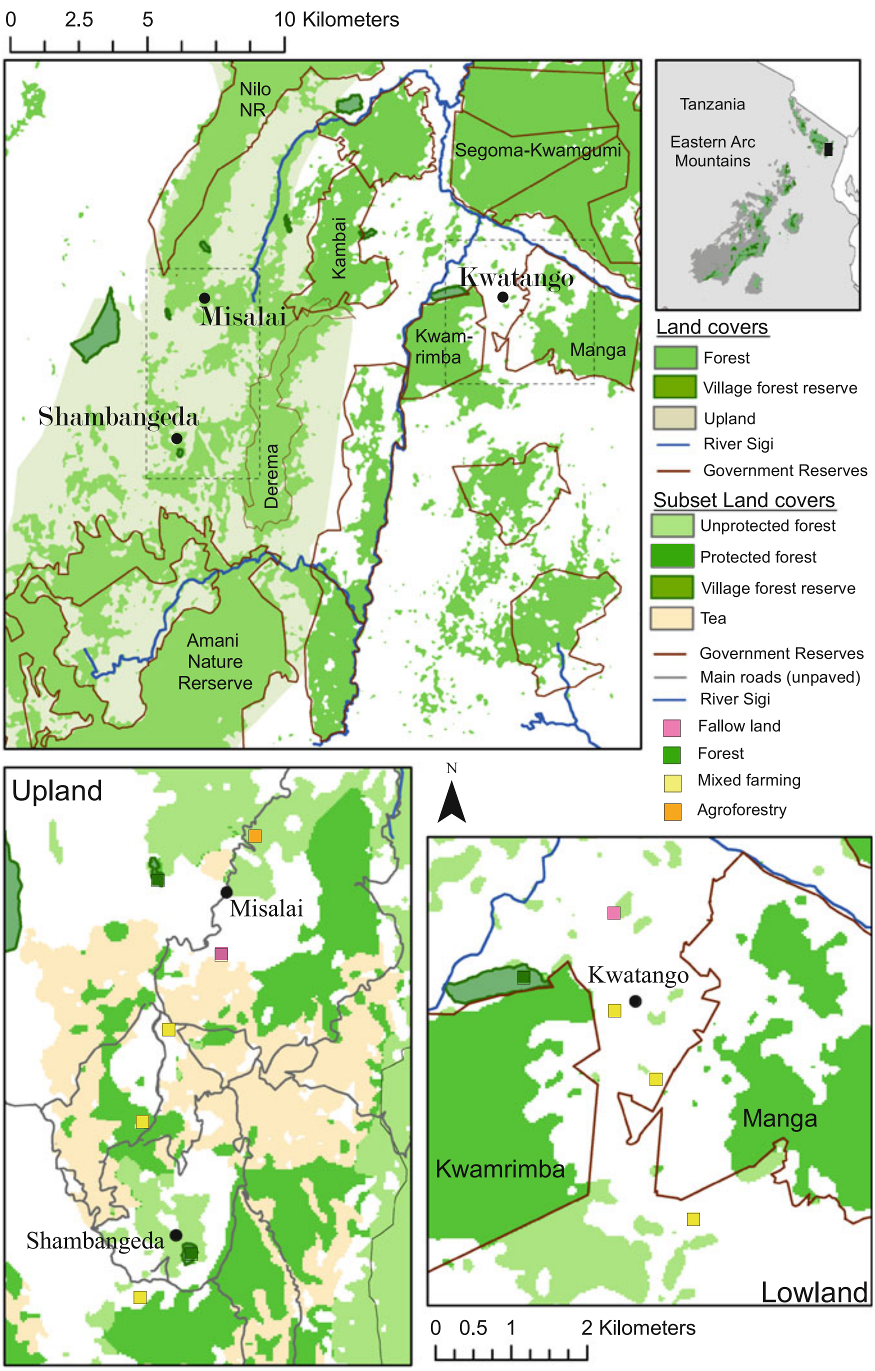

Fig. 1 Location of the Shambangeda, Misalai and Kwatango VFRs and other forest reserves in the East Usambaras. *Source*: Land cover produced with Landsat 2-23-2006 (with cloud gaps filled with land cover produced from SPOT 2-17-2007) UTMWGS84 by Jaclyn Hall

lowland montane forest zone which has a dry season and a large component of the native tree species are deciduous (Burgess et al. 2007). The lowland montane forests are very diverse, contain endemic species, and are of high conservation importance (Hall et al. 2009).

The study villages cover a mosaic of forested and non-forested land uses. The sizes of the VFRs vary from 3.7 to 37 ha (Table 1). The establishment of the VFRs has been facilitated by the TFCG.

Research Method

Plot biodiversity surveys were conducted between September 2008 to February 2009 in the upland villages of Misalai and Shambangeda and the lowland village of Kwatango. The survey team comprised trained field ecologists including a professional ornithologist Victor Mkongewa, with over 10 years of experience and trained by William Newmark, and a professional botanist Moses Mwangoka, trained by the staff of Missouri Botanical Gardens with over 15 years of experience.

Vegetation Surveys

For vegetation surveys, 0.2 ha (12 10 × 200 m transects) vegetation plots were established in the three landscapes, stratified among typical land-use types found in each village. Due to high variation in land use and small size of agricultural plots, some of the survey plots consisted of several land uses, such as fallow and monoculture, and these were classified as mixed farming landscape mosaics. Table 2 summarizes the distribution of the plots over land use types. Tree diameter at breast height (dbh) and height were measured for the tree and woody species in nested subplots: 1 × 40 m sub-plots were established for the measurement of saplings (less than 10 cm dbh), 5 × 40 m plots for the measurement of small trees (10–30 cm dbh) and the entire 10 × 200 m plot was surveyed for large trees (over 30 cm dbh). The non-woody plants were identified within the 1 × 40 m subplot.

Table 1 Area and history of past land use of the village forest reserves

Village	Size of the VFR	History of the land area now included in VFR
Kwatango	36.8 ha	The land previously belonged to individuals and the village council, and was used for collection of firewood and building materials. The villagers agreed to conserve the land in 2004
Misalai	13.3 ha	Much of the land previously belonged to individuals, some of whom cultivated cardamom and other spices; others had left the farms unused. The village council reclaimed the land for conservation in 2005
Shambangeda	3.7 ha	The area was communal village land, used for cardamom and coffee cultivation. Some land did not have a specific use according to the village leaders. The process of establishing the reserve commenced in 2002

Source: Woodcock et al. (2006); Landscape Mosaics project's data (2008–2010)

Table 2 Frequency and characteristics of vegetation plots in the various land use types and elevation zones

Location and villages	Land use type	Description	No of plots	Dominant vegetation in mosaic plots
Upland: Misalai (M) and Shambangeda (S)	Village forest reserve	Relatively natural closed forest	2	
	Agroforestry	Mixed crops, including subsistence crops, cash crops and several large trees	1	
	Fallow	Previously cultivated land, unattended for up to 3 years	1	
	Mixed farming landscape mosaic ('Mosaic')	Mixed farming, dominated by sun grown crops and shrubs, additionally a few trees	3	M: shrubs, cinnamon, cassava S1:sugarcane, ferns, sorghum S2: sugarcane, cassava, ferns, shrubs
Lowland Montane: Kwatango (K)	Village forest reserve	Relatively natural closed forest	1	
	Fallow	Previously cultivated land, unattended for up to 3 years	1	
	Mixed farming landscape mosaic ('Mosaic')	Mixed farming dominated by sun grown crops and shrubs, additionally a few trees or dominated by mixed trees (both exotic and native)	3	K1: maize, banana, tree seedlings K2: mixed trees, shrubs, weeds K3: teak and other trees, shrubs

Specimens difficult to identify in the field were collected for further identification in the National Herbarium of Tanzania. Within these plots, species identification was conducted for all floristic species including trees, saplings, herbs, shrubs and climbers. A shrub was defined as a woody plant of a species other than tree species, single or multi-stem, with a dbh of less than 10 cm.

Plant species richness was determined for plots within each elevational zone, segregating those of the upland from the lowland landscape. The basal area of each 0.2 ha plot was calculated for trees of greater than 10 cm dbh, and extrapolated for 1 ha to allow comparison with other studies. Due to the high heterogeneity of the forests, the estimate for hectare values is only indicative. The geographic ranges of

plant species were identified by a professional botanist using the Flora of Tropical Africa (FTEAs) series (1954-) and Burgess and Clarke (2000) and their status of endemism was validated using the TROPICOS database (www.tropicos.org). Their threatened status was assessed based on the IUCN Red List (IUCN 2010) and checked against newly updated lists from the most recent Red List workshop.

Because mere richness counts do not reflect conservation information, floristic richness was analyzed within the following categories: exotic, native, and forest dependent species. The exotic species included weedy invasive species such as *Maesopsis eminii* and *Lantana camara*, along with agricultural species, fruit trees and exotic timber species. Forest dependent species included endemic and near endemic species and species that were known to be forest dependent.

Bird Survey

Two methods were used to assess the bird fauna of the three landscapes: Mist netting and Timed Species Count (TSC) (Table 3). Timed Species Counts were conducted in nine vegetation plots outside the VFRs while mist netting was conducted in the vicinity of the three floristic plots established inside of each VFR. TSC have been shown to be more suitable to open environments compared to dense closed biodiverse forests. Mist netting is superior in biodiverse closed forest to positively identify birds which are not breeding. In the East Usambaras, the breeding season is from August to February but not all species breed for the whole season. This is why mist netting method was chosen for forest sites.

The TSC method was conducted by walking quietly for a period of 10 min in each vegetation plot in the morning, stopping frequently to identify and record all birds seen or calling heard. A checklist of species recorded at each plot was produced.

Ten nets were placed in a continuous line in the vicinity of the three vegetation plots in each of the VFRs for 3 days. Five of the nets were 12 m and five were 10 m. The width of the shelves was 45 cm and each net had four shelves. The nets were opened at dawn, checked hourly throughout the day and closed at dusk resulting in 1,320 net metre hours per day of netting in each site, for a total of 3,960 metre hours (Table 3). Each captured bird was identified and marked with a pen on the chest or neck in order to recognize recaptures.

The species were identified by the ornithologist with the help of guidebooks (e.g. Zimmerman et al. 1996). The forest dependency of the species, their endemic status as well as their threat status according to IUCN was identified with the help of

Table 3 Summary of sampling intensity of bird survey

Village	Total net metre hours	Period of mist netting	Number of TSC days	Period of TSC	Altitude range (m)
M	3,960	03/11—05/11/2008	3	15/02—16/02/2009	Between 958 and 1212
S	3,960	25/10—28/10/2008	3	17/02—18/02/2009	Between 887 and 971
K	3,960	30/10—01/11/2008	3	19/02—20/02/2009	Between 178 and 233

M Misalai, *K* Kwatango, *S* Shambangeda

secondary sources, including Burgess et al. (2007), Doggart et al. (2008a,b) and IUCN (2008). Due to the different methods used to detect birds inside and outside of closed forest, no direct comparison of species richness across these land covers was conducted. The analysis focused on identifying species of conservation importance and assessing forest dependency of bird species found on diverse land uses.

Results

In total, 162 plant species were recorded across all the land covers in the three rural landscapes. Of these, twenty-seven species were identified only at the genus level. These are referred to under the single term 'species'. These 162 species were from 67 families. Out of these, 102 (63%) were trees, 31 were herbs (19%), 17 were shrubs (10%) and 10 were climbers (6%) and 2 (1%) were ferns. Thirteen species were endemic or near endemic to the Eastern Arc Mountains (Table 5). One tree species, *Cynometra engleri*, was endemic to the East Usambara Mountains.

Due to the great variation in vegetation along the altitudinal gradient, it is important to distinguish between the plants identified in different zones (Lovett et al. 2006) and species data were examined separately for upland and lowland areas. Species richness and abundance of tree species varied across the land-use types (Table 4). The number of tree species recorded per sample site was typically higher in the VFRs than in other land uses. Of 162 the plant species recorded in this survey, 23 and 37 (including 10 and 13 tree species with dbh greater than 10 cm) were documented in the two 0.2 ha plots of the upland VFRs and 25 plant species (including 7 tree species with dbh greater than 10 cm) were recorded in the lowland VFR. In the upland agroforest plot, 27 plant species (including 8 tree species with dbh greater than10 cm) were recorded (Table 4). The plots of fallow in the upland and lowland supported 20 and 22 plant species, respectively.

In Misalai, 11 of the plant species found in agroforest were also found in the VFRs of the same altitude zone, which represented 27% of all species recorded in the VFRs in the uplands. The fallow in the lowland village supported 6 tree species with dbh greater than 10 cm. Only two of the tree species recorded in the lowland fallow were also found in the VFR (*Deinbollia borbonica* and *Millettia usaramensis*). In the upland fallow, none of the species recorded were found in the upland VFRs. The composition of species in the mosaic plots also differed from the species found in the VFRs. In the upland, none of the VFR species were found in the upland mosaics plots whereas in the lowland site, the species recorded in the mosaic plots represented 0-8% of the species recorded in lowland VFR.

In the VFR of Shambangeda, *Maesopsis eminii*, an invasive exotic tree, was the most common species among the large trees. In addition, 12 other tree species (with dbh greater than 10 cm) were recorded. In the agricultural landscape of Shambangeda, the dominant crops included sugarcane and cassava, and there were also a significant presence of *Pteris* sp (invasive fern), *Lantana camara* (invasive shrub) and other shrubs.

Misalai VFR contained many native secondary forest species, including *Myrianthus holstii*, *Sorindeia madagascariensis*, and *Albizia gummifera*, while the

Table 4 Total floristic species richness (including trees, saplings, herbs, shrubs, ferns and climbers) and tree species richness and basal area per ha for trees (dbh ≥10 cm) recorded in land-use types and plots

Location	Land-use type and location	No. of Exotic species	No. of native species	Forest dependent species	No. of sp recorded also in the VFRs of the same zone and % of all sp recorded in VFR	No. of species ≥10 cm DBH	Basal area (m^2/ha)
Upland	VFR (M)	–	23	18	–	10	37.7
	VFR (S)	2	35	23	–	13	40.5
	Agroforest (M)	6	21	16	11 (27%)	8	30.6
	Fallow	11	9	2	0 (0%)	4	9.1
	Mosaic (M)	12	9		0 (0%)	–	2.1
	Mosaic (S1)	6	3		0 (0%)	2	8.6
	Mosaic (S2)	9	5	1	0 (0%)	2	3.9
Lowland sub-montane	VFR	–	25	13	–	7	35.5
	Fallow	4	18	6	3 (12%)	6	13.8
	Mosaic (K1)	7	11	1	2 (8%)	2	1.4
	Mosaic (K2)	1	17	9	1 (4%)	2	7.6
	Mosaic (K3)	2	12	5	0 (0%)	7	11.9

M Misalai, *K* Kwatango, *S* Shambangeda

agroforest also contained *M. holstii* and *S. madagascariensis*, but also many *M. eminii*. Individuals of several other tree species were also recorded. *Whitfieldia elongate* (shrub), *Asplenium* sp (epiphytic fern) and *Boehmeria macrophylla* (shrub) were among the most common non-tree species recorded in the Misalai agroforest. Some coffee and cinnamon crops were also recorded.

Eighteen conservationally important tree species (endemics, near endemics, and threatened) were recorded (Table 5), mostly in the VFRs and agroforest plots. Two species, *Rytigynia lichenoxenos* and *Dialium holtzii*, were also found in mixed farming landscape mosaic in the lowland. One species, *Milicia excelsa*, was recorded in fallow and mosaic land uses in both elevational zones.

Eleven tree species identified were classified as vulnerable, one species was dependent on conservation and one was lower risk or near threatened in terms of their threatened status, as categorized by IUCN (2010), see Table 5 for details. Nine of these species occurred in the VFRs. One of them, *Allanblackia stuhlmannii*, is a near endemic tree species mostly restricted to the Eastern Arc, and one specimen having been recorded on Pemba Island. The species has commercial importance as a source of non-timber forest products—its seeds contain high quality oil and are

Table 5 Tree species of conservation importance found in the botanical survey and respective land-use types and elevations

Species	Endemic status	IUCN status	Land use type	Zone and location
Cynometra engleri	EUM endemic	Vulnerable	VFR	LL
Aoranthe penduliflora	EA endemic	Vulnerable	Agroforest	UL (M)
Isoglossa lacteal	EA endemic		VFR, Agroforest	UL (M)
Alsodeiopsis schumannii	EA endemic	Vulnerable	Agroforest	UL (M)
Rytigynia lichenoxenos	EA endemic		Mosaic	LL (K)
Allanblackia stuhlmannii	EA near endemic	Vulnerable	VFR	UL (S)
Cephalosphaera usambarensis	EA near endemic	Vulnerable	VFR	UL (S)
Cynometra longipedicellata	EA near endemic	Vulnerable	VFR	LL
Dasylepis integra	EA near endemic	Vulnerable	VFR	UL (M)
Mesogyne insignis	EA near endemic	Vulnerable	VFR	UL (S)
Dialium holtzii	EA near endemic	Vulnerable	VFR, mosaics	LL
Drypetes usambarica	EA near endemic		VFR	UL (S)
Macaranga kilimandscharica	EA near endemic		VFR	UL (M, S)
Pouteria alnifolia var. *alnifolia*	EA near endemic		VFR	LL
Drypetes gerrardinoides		Vulnerable	VFR	LL
Pavetta abyssinica var. usambarica	–	Vulnerable[a]	VFR	UL (M, S)
Rawsonia reticulate		Conservation dependent	Agroforest	UL (M)
Milicia excels		Lower risk/near threatened	Fallow, mosaics	UL (M, S) and LL

EUM East Usambara Mountains, *EA* Eastern Arc, *UL* uplands, *LL* lowland, *M* Misalai, *S* Shambangeda

[a] The species was reported as vulnerable in 1998, while the current assessment (IUCN 2010) gives no status yet states that the threatened status of the species needs updating

traded by farmers. Four of the conservationally important tree species were recorded in the Misalai agroforest.

Few species of saplings were commonly represented in each plot. In total, 180 saplings from 12 tree species were recorded in Misalai VFR. Of these saplings, 82% were *Sorindeia madagascariensis*, a common native disturbance-loving species with an edible berry but with phytotoxins in the leaves and sap related to poison ivy. In

Shambangeda VFR, 158 saplings were measured, representing 26 species, of which 43% were *Rinorea angustifolia*, a native tree restricted to moist forests, and 10% were *Cephalosphaera usambarensis*, a near endemic that is categorized as vulnerable in the IUCN red list. In Kwatango VFR, there were 72 saplings representing 19 species, of which 14% were African ebony (*Diospyros mespiliformis*), 14% were *Cola clavata*, a species restricted to East African forests, 11% were *Cynometra sp.* and 11% were *Bosqueiopsis gilletii*, a common native of dry lowland forest.

A total of 89 bird species were recorded within the three landscapes (Table 6). Of the 88 species that were categorized according to their forest dependency, 25% were strictly forest dependent, 37.5% were mainly forest dependent, and 37.5% were not dependent from forests.

Eastern Arc endemic and near-endemic bird species were found in all three landscapes and in several land use types. The banded green sunbird, *Anthreptes rubritorques*, was the only Eastern Arc endemic bird species recorded (Table 7), being found in agroforest and other agricultural lands in the uplands. In addition, six Eastern Arc near endemic species were recorded. Of these species, *Andropadus masukuensis* was found in all three VFRs, whereas *Batis mixta* was found in Kwatango VFR (37 ha) and Shambangeda VFR (3.7 ha).

All of the threatened species were found in the uplands, and one species (*Tauraco fischeri*) was found also in the fallow and mosaics of the lowlands. *Artisornis moreau*, a critically endangered bird species (IUCN 2008) was recorded only once

Table 6 Number of bird species recorded in each plot and their forest dependency

Location	Land use type and village	Capture method	No of species	Strictly forest dependent (n = 22)	Mainly forest dependent (n = 33)	Non forest-dependent (n = 33)
Uplands	VFR, S	Mist netting	10	6 (60%)	3 (30%)	1 (10%)
	VFR, M	Mist netting	9	4 (44%)	3 (33%)	2 (22%)
	Agroforest, M	TSC	33	10 (30%)	11 (33%)	12 (36%)
	Fallow, M	TSC	24	2 (8%)	8 (33%)	14 (58%)
	Mosaic, S1	TSC	29	11 (38%)	10 (34%)	8 (28%)
	Mosaic, S2	TSC	22	3 (14%)	10 (45%)	9 (41%)
	Mosaic, M	TSC	25	4 (16%)	9 (36%)	12 (48%)
Lowland montane	VFR	Mist netting	16	6 (38%)	3 (19%)	7 (43%)
	Fallow	TSC	34	3 (9%)	17 (52%)	13 (39%)
	Mosaics (K1)	TSC	30	2 (7%)	15 (52%)	12 (41%)
	Mosaics (K2)	TSC	26	3 (12%)	10 (40%)	12 (48%)
	Mosaics (K3)	TSC	24	3 (13%)	9 (39%)	11 (48%)

M Misalai, *S* Shambangeda, *K* Kwatango

Table 7 Eastern Arc endemic and near endemic bird species and vulnerable bird species

Species	Common name	Endemic status	Threat status (IUCN 2008)	Zone and location	Land cover type
Andropadus masukuensis	Shelley's greenbul	EA near endemic		UL (M, S) and LL	Agroforest, mosaics, in all VFRs
Anthreptes pallidigaster	Amani sunbird	EA near endemic	Endangered	UL (S)	Mosaic
Anthreptes rubritorques	Banded green sunbird	EA endemic	Vulnerable	UL (M, S)	Agroforest, fallow, mosaic
Artisornis moreau	Long-billed tailorbird	EA near endemic	Critically endangered	UL (M)	Agroforest
Batis mixta	Forest batis	EA near endemic		UL (S) and LL	Mosaic, VFRs (S, K)
Poeoptera kenricki	Kenrick's starling	EA near endemic		LL	Fallow, mosaic
Stactolaema olivacea	Green barbet	EA near endemic		UL (M, S) and LL	Agroforest, fallow, mosaic
Circaetus fasciolatus	Southern banded snake eagle		Near threatened	UL (S)	Mosaic
Tauraco fischeri	Fischer's turaco		Near threatened	UL (M, S) and LL	Fallow, agroforest, mosaic

EA Eastern Arc, *UL* uplands, *LL* lowland, *M* Misalai, *S* Shambangeda and K = Kwatango

in the agroforest of Misalai village. This bird species has a disjunctive distribution and is known to occur only in the nearby Nilo Nature Reserve and the Amani Plateau in Tanzania and in the Njezi plateau of northern Mozambique.

Discussion

The plant surveys conducted in the three landscapes indicate that the VFRs are important for biodiversity conservation. VFRs have a higher tree cover and plant species richness than other land uses in the rural landscapes, and considerably more endemic and near endemic plant species. Furthermore, 38–60% of the bird species found within the VFRs are strictly dependent on the forest.

Compared to government forest reserves, the VFRs are yet of lower conservation significance. They have from 7 to 13 species of trees (dbh greater than 10 cm) per 0.2 ha. The government reserves contain an average of 45 species trees (dbh greater than 30 cm) per 0.2 ha (unpublished data, Hall). This is likely due to two aspects. Firstly, the VFRs were created from land that was previously unprotected and had likely been degraded forest. Secondly, the VFRs are small compared to the government forest reserves which have an average size of about 2,200 ha. Thus the VFRs are likely to support fewer species reflecting the well documented species area relationship in the Eastern Arc forests (Newmark 2002; Burgess et al. 2007) and elsewhere (Connor and McCoy 1979; Andrén 1994). The mean size of the lowland

and upland VFRs is 16 and 5 ha respectively (not including Handei VFR which is an outlier as it lies on the steep escarpment and not on the Amani Plateau). The current size and location of the VFRs in the landscape makes them also unlikely to act as wildlife corridors that could increase survivorship of species that are sensitive to forest fragmentation. This is based on the estimated minimum width of 1 km to enable the understory bird community to survive, as suggested by Newmark (1993).

Some of the agricultural land uses, especially agroforest and fallows, support a relatively high number of plant species. In the case of agroforests, the results are supported by Hall et al. (2011). Yet, the species composition differs from the forest plots. In this study, the plant species recorded on the agricultural lands, especially on fallows, were largely different from those in the adjacent VFRs. None of the species recorded in the upland fallow were found in the upland VFRs. Only three of the 22 plant species recorded in the lowland fallow were also found in the lowland VFR. In the agroforest plot, the rate of over-lapping of the plant species found in agroforest and those found in the VFRs was 27%. The structure of land use types other than forest in the three landscapes varied considerably, as reflected in the range of basal areas. This is expected and likely due to the diversity of management decisions of land owners.

Many bird species, including rare birds, were found on agricultural land-use types. Some threatened species were found in mosaics of agricultural land, agroforests and fallow lands, suggesting that the agricultural landscape provides rare bird species habitat for part of the daily activities, as was also found by Borghesio et al. (2008). The occurrence of rare bird species in some of the agricultural land uses in our survey does not mean that protected forests are not needed to conserve birds. The bird species in the Usambaras are highly differentiated in their response to forest degradation or disturbance (Newmark 2002). Undisturbed forests are known to be critical for many species (Mori et al. 1981; Stuart 1989; Newmark 2002). Eastern Arc birds that belong to terrestrial insectivores group are most adversely affected by forest disturbance (Newmark 2006; Borghesio et al. 2008), whereas some other groups are found more abundant on slightly or moderately disturbed forested areas (Newmark 2002).

In order to assess the role of agricultural land uses in conservation of avifauna more research is needed on the breeding requirements and habitat selection of the bird species occurring in agricultural landscapes in East Usambaras. Specifically, there is a need to assess whether agroforests that are managed on low intensity and are financially profitable for local farmers can support the breeding and dispersal of avifauna of conservation concern.

Because the forest area outside the strictly protected reserves has been decreasing rapidly in the past three decades, as observed by Hall (2009), and the establishment of new central government forest reserves is often expensive and prone to social conflicts (Vihemäki 2009), it is crucial to address conservation functions of the various land uses, e.g. through village land-use planning, landscape level planning and extension services. One strategy is to create a well-designed network of tree-covered land uses by establishing new VFRs and connecting VFRs with other forests and agroforests. In addition to their conservation value, the forests and trees in the tropical landscape mosaics can support local livelihoods, e.g. by providing a

source of timber and non-timber forest products, such as wild foods (Leonard et al. 2010; Pfund et al. 2011). Another opportunity is to support agricultural practices that maintain or increase a range of native tree species as part of farming systems. The feasibility of these approaches also depends on the existing land tenure conditions, demographics, and access to alternative land and livelihood sources.

Conclusions

Village forest reserves and some of the tree-based agricultural land uses can be conducive to biodiversity conservation objectives in tropical landscape mosaics. Agricultural land uses in the East Usambaras are highly heterogeneous, with high variation in the species richness and composition. Village forest reserves, although often small in size, support a high diversity of conservationally important plant species, and more rare or restricted-range plant species compared to other land uses in the rural landscapes. The only other tree-based land use that significantly contributes to the support of native plant species is the upland agroforest. This land use is managed at low intensity and retains a high diversity of native trees in the overstory. However, agroforests are not stable constructions on a landscape. They are managed actively by the farmers and therefore sensitive to changing economic and social conditions. For instance, conversion of agroforests into sun-grown crop systems has been the trend in some upland villages in the East Usambaras (Bullock et al. 2011).

Village forest reserves support several forest dependent bird species. Traditional agroforests, fallows and mosaics contribute to conservation of some threatened bird species that are less sensitive to forest disturbance in their habitat requirements. Due to lack of population studies on each of the bird species using these areas, including their feeding versus breeding patterns, it is difficult to assess the role of agricultural land cover in sustaining bird species in the long-term (Pulliam 1988; Hughes et al. 2002).

Incorporating aspects of the rural landscape into biological conservation will become even more important as human population increases, and protected areas become increasingly isolated within a matrix of agricultural land uses. Although the rural landscape is heterogeneous, with many woody species existing in fallows, mixed farming mosaics, traditional agroforests and village forest reserves, only the latter two land uses support several conservationally important plant species. Conservation initiatives need to better integrate and balance the conservation functions with other functions of the various land uses in tropical landscape mosaics.

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